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# Material Choices for Good Load Carriage Design

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## Summary

The paper discusses the selection of fabrics, webbing, tapes, sewing threads and the issues that surround their choice in the military scenario. How infrared signature is achieved on synthetic materials, so that service personnel are hidden from night sights, is explained. A weldable material has been identified in the UK offering the opportunity to produce waterproof rucksacks. The choice of interface materials to the body is discussed and the new favoured double needle bar spacer fabric with its advantages on heat stress and load distribution capabilities is compared to the established plastic foams. The selection of buckles and the way to improve their robustness is shown. The age-old argument of internal frame versus external frame is debated.

## Fabric choices

In the UK there have been two obvious possible choices of fabric for load carriage systems, these are:

- Coated polyurethane on 1100 d/tex textured nylon; and
- Coated polyurethane on 560 d/tex textured nylon

The 1100d/tex textured nylon was chosen because the 560d/tex displayed unacceptable abrasion resistance in the field. More recently a third contender has appeared in the form of coated polyurethane on 770 d/tex textured nylon.

The properties follow the following rules: the higher the d/tex the higher the yarn diameter and the higher the fabric tensile strength; the lower the d/tex the lower the yarn diameter and the lower the equipment weight.

The abrasion needs to be assessed by field trial. Many laboratory tests have been developed for abrasion testing, but unfortunately none give reliable results in comparison to what happens in the field. This is because stiffer/stronger fabrics tend to lead with their chins thereby sustaining more damage.

## Sewing thread

Experience in the UK has clearly shown that a metric count of at least 25 (120d/tex) is necessary for military rucksacks. 50 (68d/tex) metric was favoured for commercial manufacture, but this led to catastrophic seam failures when used in the military arena. Metric measure is defined in an British Standard (BS 4134:1990), but a simple understanding is that the larger the metric count the thinner and weaker the yarn.

## Weldable fabrics

A heat/H.F.(high frequency) weldable version of the 560d/tex material exists in the UK. This opens up the possibilities of producing a fully waterproof rucksack and by incorporating a CW (chemical warfare) agent protective film, chemical protection to the contents. A totally waterproof rucksack has been produced using

this technology in our workshop. Fabrication using welding is more expensive than sewing and because of the welding tools item shape is more restrictive.

## Colour

The choice of colour is very simple for the military and it is either olive drab or disruptive pattern print (DPM). The difficulty lies with achieving the correct infra red reflectance (IRR). In the case of the olive drab this is achieved by incorporating selected pigments in the PU coating. In the case of the DPM, pigment printing with selected pigments will achieve the correct result. Conventional printing with acid dyes will produce better colour fastness, but will not give the desired IRR result. The colour fastness of the pigment print was checked by repeated trialling of the kit around an assault course where it was established that the fabric wore out before the print faded.

## Buckles And Fittings

Buckles can be manufactured from metal or plastic. In common with other NATO nations the UK chose the more cost effective option of plastic. The choice of plastic is critical. The UK chose Acetyl for the ladderlock buckles and replaced nylon by Delrin500T for the side release buckles. The nylon side release buckles were initially trialled, but gave too many failures.

New generations of buckles which are lighter and stronger are currently available from ITW Nexus. Although these buckles are fully compatible in their range, they are not compatible with the existing buckles.

## Webbings and Tapes

The webbing and the buckles need to be fully compatible so that easy run through and lock is achieved. Nylon webbing is currently the choice of UK MoD because of its better abrasion resistance, although it suffers more from creep than polyester. IRR is built into the webbing and tapes by the incorporation of a fine d/tex black spun coloured yarn in the weft. If the correct proportion of black spun coloured yarns to green yarns are used, the NATO specification for IRR is consistently achieved.

## Interface Materials

Outlined below are a number of choices for interface materials:

- Polyethylene closed cell.
- Open cell foams
- Foam combinations
- PU (Polyurethane) foams
- Phase change foam.
- Double needle bar mono-filament fabric

***Polyethylene closed cell foam.*** This has been the most popular choice for military rucksacks, but the compression and recoverability are critical and need to be highly specified. An illustration is given below:

- Typical UK figures tested to BS 4443
- Method2 Density  $33 \pm 5$  Kg/cu. m.
- Method 3A Tensile strength 275-450kPa
- Elongation 90% min.
- Method5A Compression Stress
- 25%  $40 \pm 10$  kPa
- 50%  $105 \pm 20$  kPa
- Method 6B Compression set RT25%(24Hrec) 5-10%

**Open cell foams.** Open cell foams have been used extensively in the commercial world, but they suffer from a lack of durability, robustness and they absorb water, which adds weight and creates discomfort in the rain, and CW agents and are therefore unsuitable for military use. They are more comfortable initially.

**Foam combinations.** Foam combinations could offer a possible compromise, but the durability, water and CW agent absorption makes the choice unsuitable for the military.

**Polyurethane (PU) foams.** There has been a new development in PU foams called Confor foam which conforms to extreme shapes, but when the pressure is removed converts back to its original shape. This material was developed to protect drivers in Formula 1 cars. Its open cell nature could make it unsuitable for use in military rucksacks.

**Phase change foam .** Phase change foam absorbs body heat until all the latent heat is fully exhausted. This could prevent overheating at the interface by maintaining a constant temperature. Unfortunately, all the current samples lack durability and are totally unsuitable for use.

**Double needle bar mono-filament fabric.** This is the most exciting development that has occurred in novel interface materials. Although they are currently heavier than polyethylene foams, they are more durable, have better recoverability, allow the heat and sweat to escape from the body(Loughborough University evaluation) and are highly specified and controlled by the car industry. Special Forces have nominated the new “air-mesh rucksack” as their choice for the future. UK commercial companies, CQC Ltd., have begun to take advantage of this technology.

### Comparison of foam/spacer fabric weights

The table below gives an appreciation of the weights of the different interfaces and aids the designer in making his or her choice.

Description	Weight (g/sq.m)	Quality no.
90patt. foam	476	
Grooved airmesh	823/760	N1702
White airmesh	605/650	N2508
Muller airmesh	686	
Black mesh face airmesh	804/750	N1685
Mesh	485	UK/SC/5188
PU Confor	1150	CF-47050

### Frame choice

The most important choices when considering the frame is whether it should be external or internal, plastic or metal and any form of sizing adjustment.

The internal frame is currently favoured by most UK manufacturers and it has normally been made from metal, but more recently plastic has begun to appear. The internal frame allows the rucksack to fit nearer the center of gravity of the body. Multi-prong frames are favoured to try to improve the load distribution. External frames allow heat and sweat to escape. New integrated frames with size adjustment are beginning to appear in the UK market place.

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